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CONFERENCE OF EMPIRE METEOROLOGISTS, 1929.

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AGRICULTURAL SECTION.

AGRICULTURAL METEOROLOGY.

IN

G E R M A N Y.

THE ORGANISATION OF AGRICULTURAL METEOROLOGY IN GERMANY

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Introduction. Agriculture and agricultural science are dependent on numerous cognate sciences, for instance chemistry, physics, botany, zoology, geology, soil science, meteorology, climatology, bacteriology and many others. In the case of some of these sciences the co-operation with agriculture is close. In Germany the earliest and most complete co-operation has been with chemistry, in the form of agricultural chemical experimental stations. The importance of meteorology for all branches of agriculture has been recognised from ancient times, and attention has always been paid to meteorology in practical and scientific agriculture, but for the most part in an unsystematic way and by methods which are based on unsure foundations.

Meteorology itself developed very strongly about the middle of the nineteenth century and gradually became recognised as a separate science. Repeated attempts were made thereafter in Germany to improve and systematise the connection between meteorology and agriculture. Recent meteorological development has reference almost exclusively to short term weather forecasts. Such short term forecasts were regarded as the direction in which meteorology could be most useful to the general public. The use of meteorological observations for geography (especially agriculture and climatology) developed only very gradually in comparison and was mostly limited to scientific circles. Although the relations between meteorology and biological phenomena in plants and animals and the changes in the soil, have only recently been brought under scientific review, the use of meteorology both by the practical and scientific agriculturist is now recognised as most important in Germany.

It is only recently that it has been understood that while short term weather forecasts used rightly can be of great and manifold use to the agriculturist, this use has only a limited value, mostly for less important problems; that while long term forecasts are very much to be desired for agriculture they are not yet possible; and that the most important and most useful objective is the investigation of relations between meteorology and all agricultural problems. Agriculture (in particular arable and livestock breeding) urgently needs an exact knowledge of the fundamental conditions on which practice is based, a knowledge not merely of the processes and constituents of the soil, but also of the forces and materials in the atmosphere. Agricultural meteorological knowledge is as important as agricultural soil knowledge.

The effects of meteorological processes differ with different soil conditions and with different kinds and varieties of plants so that agricultural meteorology is a branch of agricultural science; pure meteorology furnishes the basis for this branch of science, but cannot provide for the utilisation of the results for agriculture. The tasks of pure meteorology consist in the investigation of weather processes, the explanation of laws governing these processes, the drawing up of rules for the carrying out of meteorological observations, and the construction and utilisation of apparatus. But the carrying out of meteorological observations in agricultural investigations, and the utilisation of the results in agriculture form the domain of the practical and scientific agriculturist and constitute agricultural

meteorology. The use of weather forecasting for agriculture is the domain of pure meteorology, although it is for the agriculturist to make practical use of the forecasts.

In the use of meteorology in agriculture the co-operation of the pure meteorologist is obviously indispensable. Attempts to solve agricultural meteorological problems in purely meteorological circles however have been unsatisfactory, even according to meteorologists themselves, and it has become urgent in Germany for these problems to be investigated in practical and scientific agriculture with the co-operation of the pure meteorologist. Further, it has been recognised as necessary (especially by the various Congresses which have dealt with the organisation of agricultural meteorology) to spread a greater knowledge of meteorology among agriculturists. In order that there should be no lack of teachers, instruction in meteorology is given in all schools; in the case of high schools, partly in connection with physics and partly with geography. The object has been to give an understanding of weather maps and of the causes, the distribution and the meaning of meteorological processes (precipitation, temperature, sunshine and wind). It has been emphasised that the most valuable results of meteorology must often remain without use for wider circles if these circles themselves do not possess a certain basis of knowledge as to their problems. This has been attained in agricultural circles by carrying out suitable meteorological observations; thus, measurement of precipitation, observations of air temperature, clouds and wind direction have been widespread. Agricultural calendars and day-books have provided for records of the results of such observations; and chambers of agriculture publish the results periodically. It is becoming ever more evident that the weather forecasts prepared by pure meteorologists are better understood and utilised by those agriculturists who themselves regularly carry out meteorological observations than by those who have never had a close acquaintance with meteorology. The observations have many uses both in farm management and in field experiments and variety trials, so that they are an indispensable part of the business of farming. Lastly, students of practical agriculture, for whom after a two years' course a students' examination is held by chambers of agriculture, have been interested to a certain extent in weather processes.

As a result of the issue from February 1876 onwards by the German "Sea watch"* in Hamburg of weather news in connection with storm warnings on the German coasts the desire was expressed from many sides that this service should be made available for further circles and especially for agriculture. At the instance of the Admiralty the Sea watch published daily weather maps in numerous daily papers especially in the interests of agriculture.

The Conference at Kassel 1878. In 1878 a conference was held in Kassel of representatives of Government Departments, of administrative bodies, of pure meteorology and of practical and scientific agriculture, to advise on the organisation of an agricultural weather service and especially on the utilisation of weather forecasts for agriculture.

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*"Seawarte": An organisation for collecting and disseminating information of value to shipping such as amendments to charts, location of coaling stations, water supply, depths of harbours, etc. It appears to have somewhat wider functions than Trinity House.

In the transactions of this Congress the claims of agriculture as regards weather forecasts were set out as follows:-

"Although knowledge of past weather is useful in general to German agriculturists, the latter have a special interest in forecasts of (1) rainfall, (2) storms, (3) night frosts. The importance of forecasts is less in winter. Forecasts are only of value in agriculture when they are available in good time so that protective measures against bad effects can be taken by arranging field work accordingly. As such arrangement is only possible in the day time and can seldom be done at night, it is important that forecasts should be available as early as possible in the afternoon of the day previous to that to which they relate. It is important that dispatch of weather information should take place with such regularity that each alteration to be expected in the weather is brought at the right time to the notice of agriculturists; dispatch should, therefore, also take place on Sundays and holidays. In weather forecasts all vague expressions should be avoided. It is important to agriculturists that indication should be given (as far as this is possible for meteorological science) of the quantity of rain or duration of the rain period and the continuation of the indicated weather. Agriculturists can derive no special value from scientific forecasts when these do not exceed in reliability the forecasts of empiricists. It appears, therefore, important that the German Empire should be divided into climatic districts and that telegrams for each should only be issued by meteorologists of standing. The value in the national economy of reliable and early forecasts for the whole of the country lies in the fact that they make it possible to protect foodstuffs from damage. It appears, therefore, that the Government would be justified (1) in bearing the cost of establishing and maintaining a central authority for weather telegrams for the German Empire, (2) in dispatching gratis or at a very low cost all weather telegrams, (3) in arranging for the most speedy dispatch and receipt of forecasts. The cost of the establishment and maintenance of district meteorological offices and of the weather telegrams sent to the latter by the central station would be met from public sources in the districts in question, but the costs of the further dispatch of telegrams to the telegraphic offices of the districts and to agriculturists would be borne by those interested."

In the transactions of the Congress of 1878 at Kassel, the importance of weather forecasts for agriculture was recognised by all. The wish was also expressed that preparation and dispatch of forecasts should be speeded up so that practical agriculturists could use them in their daily arrangements. It was further thought to be absolutely necessary that renewed attempts should be made to draw up weather forecasts relating to longer periods. Emphasis was laid on the point that weather forecasts were not the only method of using meteorology for agriculture, and that exact observations on weather phenomena (rainfall, humidity, wind and cloud) and research as to the effect of these factors on the life activity of plants and animals constituted at least equally important work.

Developments following the Congress at Kassel. Observations of important weather phenomena (principally temperature, rainfall, wind direction and cloud), and the regular daily inscription of weather conditions in the farm day books and calendars became more and more widespread in practical circles, and formed an

indispensable part of scientific experiments in agriculture and animal husbandry. Meteorological and climatic points of view, and the results of meteorological observations formed the basis of schemes and deductions in agricultural economics and agricultural statistics as well. The observations of numerous meteorological stations of the second and third order, founded by the Prussian Meteorological Institute of Berlin, and of rain and weather stations were used in such work. These Stations had only in isolated cases and purely accidentally any direct connection with agriculture and were principally founded for the purposes of pure meteorological science. They were situated mostly in towns where it was possible to secure regular observations both in winter and summer. The net-work of these meteorological stations is comparatively thick in Prussia.

A net-work of observation stations was set up by the German 'Sea Watch' in Hamburg on the North and East coasts. In North Germany a meteorological observation service was founded by the Forest Administration in all forest areas; here observations were made similar to those of meteorological stations of the second and third order, and were applied in forestry. In other German districts also a very wide-spread net of stations for meteorological observations was set up at first for the purpose of pure meteorology.

Present utilisation of meteorological knowledge in agriculture. The utilisation of meteorological knowledge is now common in all branches of agricultural science and practice, for which it is regarded as indispensable and as serving for the increase of agricultural production. Thus, the testing of crop varieties is continuously carried out in the endeavour to discover superior varieties suited to the different districts. This is the chief direction in which meteorology can assist the improvement of agricultural production in Germany. The correct distribution of the cultivation of rye, wheat, spelt, spring wheat, winter and spring barley, spring oats, as compared with winter oats, maize, rape and rape seed in all districts is one of the chief results of the utilisation of the results of meteorology by practical and scientific agriculture in Germany.

Also in animal breeding, the distribution of races and breeds throughout the Germany Empire, and their improvement are based on meteorological results whose further application to local breed peculiarities would be of great value for animal breeding and animal husbandry. A few results are the following:- The relation between relative humidity in the coastal and mountain districts and the milk yield of cows, as well as the hides of animals; the influence of the yearly rainfall and its monthly distribution on the cultivation of the principal fodder plants (clover, lucerne, grasses, pastures and meadows; the delimitation of districts suited to the different German native races of sheep from those suited to imported Spanish merinos and English races.

In the realm of plant diseases, the question of the winter killing of winter rye, wheat, oats, rape, and rape seed, and winter peas has been thoroughly investigated in practical and scientific experiments, above all in connection with the selection and breeding of suitable varieties and the time of sowing.

Further, it has been proved that the appearance and spread of rust in wheat and oats depend on the weather as is also the case with numerous other diseases and pests of cereals, rape, roots, potatoes, garden plants, fruit, vines, tobacco, hops, flax, etc.

Also in the realm of farm management or agricultural economics, agricultural weather knowledge finds practical and scientific utilisation; in the choice of the most suitable farm organisation the results of meteorology have usually been decisive; and they have been continuously utilised in the distribution of labour between arable and livestock districts and districts of mixed holdings. Among related questions which are being further examined can be instanced:- the extension of permanent grass; potato growing in connection with spirit production and animal husbandry; and the provision of agricultural buildings, stalls and barns. The distribution and proper organisation of agricultural labour, the necessity for fallow and other questions on which the success of farming so largely depends are to be investigated, not merely from the point of view of soils, but also from that of agricultural weather conditions.

Weather Forecasts. Although weather forecasts are a very popular topic they are not so important for the big agricultural problems, as are the other questions discussed above and this view is better appreciated in agricultural than in purely meteorological circles. The use of weather forecasts as far as they have been developed up to the present, i.e. for a day in advance, enables the farmer to arrange his management for the next day, or even for the afternoon in the morning of the same day. However, it is impossible to avoid errors in forecasts. The farmer who rigidly follows weather forecasts will often suffer damage, that another, who does not rely on forecasts will not. Such examples cannot be counteracted by the cases in which an advantage is obtained through forecasts. The practical farmer has, therefore, continual misgivings about the forecasts which he receives. These misgivings are very much lessened if he makes the forecasts himself or co-operates as an observer and as a user of the daily weather charts.

The requirements of agriculture in relation to weather forecasts are as follows:-

(1) Certainty in short term forecasts and rapidity of distribution.

(2) Information as to the likely quantity and duration of rainfall, and on the temperature, especially in "transition" periods of the year.

(3) Endeavours to forecast for long periods, not necessarily the various factors in the weather, but the ruling character of the weather, e.g. whether a winter will be hard or mild, whether a summer will be wet or dry, whether harvest time will be rainy or not.

This last requirement of agriculture from meteorology is of especial importance. If it could be implemented many heavy losses in farm management would be avoided.

Since the Congress at Kassel of 1878, the forecast service of the German "Sea Watch" at Hamburg has been extended to very many districts and has been completed as far as possible

To obtain further improvements the German Ministry of the Interior called a Conference in May 1900 at the office of the German "Sea Watch" in Hamburg, consisting of representatives of the central meteorological stations, of practical agriculturists and of the authorities concerned. The object was the transfer of a regular telegraphic weather service to the Government, and its stronger organisation. In the transactions of the Conference the

following wishes of agricultural representatives are recorded:

(1) It is urgently necessary that regard should be paid to meteorology in universities and high schools to a much greater degree than hitherto, and that in particular teachers of natural sciences at the high schools, the middle schools, etc. should have an opportunity of acquiring knowledge of this subject and of including it in their teaching.

(2) In view of the big differences in local weather circumstances of which weather forecasts and meteorological comparisons cannot take sufficient account, it appears desirable that local rainfall in its yearly distribution and in its relation to winds of various directions, should be thoroughly ascertained and set out on charts.

(3) As supplementary to these local rainfall charts, and to establish a connection between weather and agriculture, charts of agricultural crops are of special value.

The following resolutions were passed as to the organisation of weather forecasting -

It is highly desirable that studies should be energetically prosecuted for the purposes of forecasts for long periods and encouragement should be given by the Government to such studies. The general interest of the farmer in, and his understanding of, weather forecasts, should be secured (a) through meteorological instruction in agricultural schools, (b) through lectures by peripatetic agricultural instructors, (c) through the publication of reports on the weather situation in agricultural periodicals, (d) through the issue of a pamphlet which could be generally understood, on the practical use of weather tables and weather charts and the basing of forecasts on these.

Organisation of the German Weather Service. The German weather service is organised in the following way:-

The weather service and the meteorological observations and scientific investigations on atmospheric phenomena are carried on by the following:-

(1) The North German weather service for Prussia, including Hesse, Mecklenburg-Schwerin and Strelitz, Oldenburg, Brunswick, Anhalt, Waldeck, Lippe, Lubeck, Bremen and Hamburg, is administered by the Prussian Ministry of Agriculture, Lands and Forests.

(2) The weather service for the South German States is administered by the Governments of the different States.

(3) The German "Sea Watch", formerly under the Imperial Marine Office, now belongs to the Imperial Ministry of Trade.

The marine and air weather service, which was established during the war, was placed after the war under the German "Sea Watch" and therefore is now also under the Imperial Ministry of Trade.

The weather service mentioned in (1) and (2) has existed since 1903, and was established with the object of securing general utilisation of meteorological observations through the construction and distribution of weather charts and weather forecasts. The cost of telegraphic dispatch of forecasts to all the telegraphic institutes is borne by Imperial funds, and repaid to the postal administrations of the States. Salaries of staff and maintenance costs of weather services are

borne by the individual States.

Repeated conferences of experts have been held in the Imperial Economic Ministry with a view to the further development of the German Imperial weather service from which the following have resulted:-

1. The German Empire organises and maintains an Imperial Weather Service which has the duty of meeting the needs for weather forecasts on land, on sea, and in the air.

2. The Imperial Weather Service carries out its work in co-operation with the existing meteorological institute of the Empire and its States, whose net-work of stations and scientific facilities are put at his disposal. The general and regional scientific work of this institute (meteorological investigations, climatological and magnetic survey of the country, air investigations, sea investigations, etc.) remains thereby unaltered.

3. The district distribution of weather forecasts and weather charts is carried out by 8 principal stations and a number of subsidiary stations. Principal stations are so equipped with personnel and wireless apparatus that they can themselves receive all foreign wireless messages. The boundaries of forecast districts are fixed from the points of view of climate and communications.

4. Hamburg has such facilities as the station for information that it can transmit reports, wireless and telegrams coming from abroad as well as the interior, to other principal stations by a wireless telegram containing the whole of such information.

5. The 8 principal stations of the Imperial Weather Service are attached to the German "Sea Watch" at Hamburg, the "Weather Watch" at Konigsburg, the Prussian Meteorological Institute in Berlin, the Meteorological Geophysical Institute of the University of Frankfort a.M., and the Land "Weather Watches" of Dresden, Karlsruhe and Munich. The establishment of a principal station in Cologne is to be carried out at the earliest possible moment.

6. The service of air information is attached to the aeronautical observatory at Lindenburg. This is the central station for observations on the upper atmosphere and transmits its information to the interior and abroad by telegraph and wireless. For this purpose it is equipped as a transmitting station.

The North German weather service is organised in the following way:-

(1) The area coming under the North German Weather Service organisation is divided into weather service districts. In each district there is a weather service station. The situations of weather service stations are at present: Konigsberg, Breslau, Berlin, Magdeburg, Hamburg, Aachen, Weilburg and Frankfort a.M. In close collaboration with these stations is the Thuringian weather service station of Ilmenau. Alterations of boundaries are notified through the issue of charts.

(2) Subsidiary weather stations can be established at need. Their work and their relation to the weather service station in whose district they are situated are settled and announced from time to time. Subsidiary weather service stations which issue their own weather charts are in Essen and Treves.

A council is attached to the Imperial Ministry for Food and Agriculture consisting of experts and of interested persons, with the duty of further developing the weather service. The following resolutions taken from the transactions of this body as regards the utilisation of meteorology for agriculture may be noted. "To secure the greatest possible extension of weather knowledge throughout the land the youth of the country must be taught the weather organisation and the importance of weather service publications. For this purpose weather instruction must be included in the curriculum of all schools, peoples' schools and technical schools, as well as the high schools, as an obligatory subject. In order to make instruction in this subject of value, the teachers should themselves be instructed by expert meteorologists and the heads of public weather service stations. The use of weather charts as teaching material should be prescribed by the central authorities for every school".

In this resolution it is acknowledged that the utilisation of the results of the weather service by agriculturists depends on the capacity of the latter to profit by them. Forecasts lead more easily to errors and misunderstandings when used injudiciously, than when used with an understanding of the methods on which they are prepared.

The various Universities and technical high schools of Germany carry on more or less extended observations at meteorological stations, which furnish at the same time teaching material for lectures on general and applied meteorology, and provide exercises in the carrying out of observations, in meteorological calculations, and in the construction of weather charts. The Professor entrusted with this branch of science has the opportunity of investigating meteorological problems through his own work or that of his scholars. Agricultural weather knowledge is imparted through an examination of the chief agricultural questions from the meteorological point of view and also by the examination of a meteorological problem in its effect on agricultural questions, (crops, animal breeding and farm management).

Special Phenological Organisation. Recently a meteorological phenological laboratory has been established at the Imperial Biological Institute for Agriculture and Forestry at Berlin, which has covered the Empire with a network of observers. This subject is especially concerned with the study of the relations of plant diseases and pests to weather factors. For observations of the weather, phenological data are collected in addition to purely meteorological data. Phenological observations are not a substitute for meteorological observations but a valuable supplement to them, particularly as regards their utilisation in agriculture, horticulture and forestry.

A scheme for phenological observations drawn up by Professor Drude which is used in Central Germany is as follows:-

Observer ..... Place .....

Position of Station ..... Altitude .....

Day numbers which should be used in place of the customary figures of dates.

February.. 9 - 50, Febr.14 - 55, Febr. 19 - 60, Febr. 24 - 65.

March .... 1 - 70, M.6 -75, M.11 -80, M.16 -85, M.21 -90, M.26 -95, M.31 -100.

April .... 5 -105, A.10 -110, A.15 -115, A.20 - 120, A.25 -125, A.30 - 130.

May ..... 5 -135, M.10 -140, M.15 -145, M.20 -150, M.25 -155, M.30 -160.

June ..... 4 -165, J.9 -170, J.14 -175, J.19 -180, J.24 -185, J.29 -190

July ..... 4 -195, Jl.9 -200, Jl.19 -210, Jl.29 -220.

August ... 8 -230, A.18 -240, A.28 -250.

September. 7 -260, S.17 -270, S.27 -280.

October .. 2 -285, O.7 -290, O.12 -295, O.17 -300, O.22 -305, O.27-310

In leap years these figures from the 1st of March onwards will be increased by one.

Abbreviations.

e.Bl..... Beginning of Blossoming.

v.Bl..... Beginning of full flower (in Clover fields and meadows).

B.O.I..... Breaking into leaf.

B.O.II ..... Unfolding of leaf.

Fr..... Beginning of ripening of fruit.

E..... Harvest.

L.V..... General autumn leaf changes.

L.F..... General defoliation.

H.R..... Autumn ripening of the young shoots of fruit trees.

REMARKS OF THE OBSERVER.

o.	Abbreviation	Observational plants.	Date
1.	e.Bl.	Galanthus nivalis	
2.	e.Bl.	Cornus mas	
3.	B.C.I.	Aesculus Hippocastanum	
4.	B.C.II.	" "	
5.	e.Bl.	Narcissus Pseudonarcissus	
6.	B.C.I.	Tilia grandifolia	
	B.C.II.	" "	
7.	B.C.I.	Betula alba (+ verrucosa)	
	B.C.II.	" " "	
8.	e.Bl.	" " "	
9.	e.Bl.	Ribes Grossularia	
10.	e.Bl.	Prunus avium	
11.	e.Bl.	Prunus Cerasus	
12.	e.Bl.	Prunus communis	
		other varieties	
13.	e.Bl.	Prunus Padus	
14.	e.Bl.	Pirus Malus	
		Other early blossoming varieties	
		Other late blossoming varieties.	
15.	e.Bl.	Vaccinium Myrtillus	
16.	B.C.I.	Sorbus aucuparia	
	B.C.II.	" "	
17.	B.C.I.	Fagus Silvatica	
	B.C.II.	" "	
18.	e.Bl.	Aesculus Hippocastanum	
19.	e.Bl.	Syringa vulgaris	
20.	B.C.I.	Fraxinus excelsior	
	B.C.II.	" "	
21.	e.Bl.	Sorbus aucuparia	
22.	e.Bl.	Cytisus Laburnum	

No.	Abbreviation	Observational plants	Date
23.	v.Bl.	Alopecurus pratensis	
24.	v.Bl.	Dactylis glomerata	
25.	v.Bl.	Phleum pratense	
26.	v.Bl.	Clover (Trifolium pratense)	
27.	e.Bl.	Sambucus nigra (variety and position)	
28.	e.Bl.	Vitis vinifera	
29.	e.Bl	Tilia grandifolia	
30.	e.Bl.	Lilium candidum.	
31.	e.Bl.	Field of Secale cereale hibernum	
32.	E.	Cutting of the field	
		Interval between Bl, and E.	
33.	e.Bl.	Field of Secale cereale aestivum	
		Interval between Bl. and E.	
34.	E.	Cutting of this field	
35.	e.Bl.	Colchicum autumnale	
36.	Fr.	Aesculus Hippocastanum	
		Interval between Bl. and Fr.	
37.	Fr.	Vitis vinifera (as Nr.28)	
		Interval between Bl. and Fr.	
		Notes on vintage	
38.	L.V.	Aesculus Hippocastanum	
39.	L.V.	Fagus silvatica	
40.	L.V.	Betula alba	
39a.	H.R.	Pirus communis	
40a.	H.R.	Pirus malus	
41.	L.F.	Fraxinus excelsior.	

Chief spring phase in valleys and lower mountain districts.

	e.Bl.	Prunus padus .....
	e.Bl.	Pirus communis .....
	e.Bl.	Pirus malus .....
B.O. $\frac{I+II}{2}$		Fagus silvatica .....
		Average .....

Problems of Agricultural Meteorology. The following selection of agricultural meteorological problems gives an idea of the work to be undertaken:

1. Weather forecasts for long periods.
   Next, the connection of weather factors with:
2. Mildew.
3. Rust.
4. Blight.
5. Plant lice.
6. The distribution of winter hardy and winter killed wheat. varieties.
7. Extension of the cultivation of maize for grain.
8. The limits of lucerne cultivation.
9. Conditions of growth of clover and lucerne seed.
10. Data for grass seed culture.
11. Change of seed with cereals, especially oats, and potatoes.
12. Sugar content of roots.
13. Quality of tobacco.
14. Quality of wine.
15. Quality of hops.
16. Quality of flax.
17. Cultivation of aromatic plants - caraway, fennel, peppermint.
18. Cultivation of poppies for seed, oil and opium.
19. The protein and starch content of wheat.
20. Do. of barley.
21. The oil content of rape seed and linseed.
22. Quality of hemp.
23. Fungus diseases of peas, especially Ascochyta and pea leaf roll.
24. Fungus diseases of lupins.
25. Determination of seeding times, among others of cereals, roots and potatoes.

These are instances of the problems (the number of which could be considerably extended) whose successful solution would help to safeguard and increase agricultural production. If the various processes of plant life are explained, means will be found to support the favourable effects and to mitigate or avoid the destructive effects of weather. This will be the real utilisation of meteorology in agriculture, for which pure meteorology and also phenology afford both the bases and the material for study.

The centralising and working up of material and the initiation of investigations is the business of agricultural science which is in a position to connect up scientific work with economic utilisation of results. This cannot be achieved either by treating the problems purely from the meteorological side: or from the botanical, zoological, biological or chemical side alone. Agricultural meteorology is a part of agricultural science and like the latter, needs the collaboration of many other sciences. Only the final utilisation of results in agriculture is beyond its scope.

The Agricultural Meteorological Council of the Ministry for Food and Forestry. Following the resolutions of the International Agricultural Institute in Rome, a council has been formed at the Ministry for Food and Forestry for the purpose of fostering agricultural meteorology. In this council agricultural science, pure meteorology, the Imperial Biological Institute for Agriculture and Forestry, the Institute for Agriculture and Forestry, and the Institute for Irrigation are all represented. The deliberations of this body have led to the following conclusions:

1. The formation of a central institute for agricultural meteorology should not be attempted. This work should rather be de-centralised at agricultural scientific institutes, at universities and high schools, at the Imperial Biological Institute for Agriculture and Forestry, at the Meteorological Institute, and at the Institute for Irrigation. The co-operation of the statistical authorities is desirable.

2. The mapping of the country in regard to agricultural meteorology should be carried further.

3. The collection and working up of agricultural phenological data have been taken over by the Imperial Biological Institute for Agriculture and Forestry. The aim is to utilise the data for the forecasting of harvest results, and to improve them for the purpose.

4. The preparation of long period weather forecasts must be kept constantly in view as an important task of pure meteorology for the benefit of agriculture. It is less a question of forecasting all factors of the future weather than of forecasting the general character of future weather.

5. The Institute for Irrigation attacks especially questions of evaporation which are of importance in the biological processes of agricultural plants and animals.

Conclusion. In the province of agricultural science agricultural meteorology has up to the present not been entirely neglected; regard to it is paid in nearly all agricultural scientific work; yet for the most part it is not sufficiently emphasised that meteorological processes (temperature, sunshine, humidity and rainfall) provide real sources of energy on which plant and animal production depend. They form (with the soil as the chief source of material and the life factor as the basis of all agricultural processes) one of the three principal factors in agriculture. It is imperatively necessary that meteorological elements should be taken into effective consideration in scientific and practical work on agricultural questions. Observational material is abundantly available, although its further extension on the agricultural side is desirable. There are many theses in the realm of agricultural meteorology, of which a selection has been given above, in the study of which the soil, and the life factor of plants and animals, cannot be omitted. Pure meteorology is not sufficiently in a position to undertake these tasks, but they are an essential part of our agricultural science which, in other respects widely developed, has not up to the present made sufficient use of the results of meteorology.

The following are replies to the specific questions put to Professor Holdefleiss.

1. <u>The supply of long and short term forecasts for farmers, fruit growers, etc.</u>

The arrangements for weather forecasts in Germany are centralised at the German "Sea Watch" in Hamburg. This is a purely meteorological institute serving all interests and not specially those of agriculture. Its weather forecasts and weather maps contain no agricultural information. The German "Sea Watch" received weather reports from the whole of the northern hemisphere outside the tropics and constructs daily weather maps. On each weather map six separate maps are displayed: viz. three maps of Europe and the North Atlantic for 14, 19 and 8 o'clock; a map of the Northern Hemisphere with particulars of pressure,

temperature, wind and condition of the sky at 2 o'clock; a map of pressure changes in millimetres over Europe from 5 to 8 o'clock; and a map with isotherms and rainfall districts for 8 o'clock. Further, there are on the back of the map, and in a supplement, weather reports of the German Stations for 14, 19 and 8 o'clock on pressure, wind, weather, air temperature, pressure changes, course of the weather since last information, visibility, extent and character of the clouds, relative humidity, state of the sea and height of clouds; and also much the same data from other European Stations, from ships' observations, from balloons as regards the upper air, and hourly records of the self-recording apparatus in Hamburg. Finally, the weather map contains a description of the whole of the weather position at 8 o'clock with the probable course of the weather for the next period. Further the German "Sea Watch" distributes particulars of weather information it receives to the principal Stations throughout the various districts of Germany. It also publishes a weekly weather report which gives for every day of the week two weather maps of Western Europe for 8 and 19 o'clock also 14 weather maps and a map of the Northern Hemisphere for the first day of the week at 2 o'clock. Curves are also included of the course of pressure, temperature, wind direction and velocity based on records of the German "Sea Watch" in Hamburg. In tables relating to some of the principal stations of Germany the daily maxima and minima of temperature and quantity of rain are given and finally there is a thorough description in words of the whole course of the weather during the week under review, purely from a meteorological standpoint. These weather reports on a past week principally serve to spread a knowledge of meteorological processes and facilitate the co-operation of all those who are interested in the causation of the weather and who wish to use meteorological apparatus.

The weather report for the Northern Hemisphere compiled in the German "Sea Watch" at Hamburg, is put to further use daily through the 16 public weather stations set up in the different parts of the country with the support of the Ministry of Agriculture. These stations are in Konigsberg, Berlin, Stettin, Magdeburg, Hamburg, Bremen, Essen, Aachen, Frankfurt am Main, Giessen, Breslau, Weimar, Munich, Karlsruhe, Stuttgart and Dresden. These weather service stations give a weather map of the situation in Europe at eight o'clock which is distributed in their areas at about 11 o'clock so that in the neighbourhood of any station it reaches those interested at about 13 o'clock. In addition to the weather maps, the observational results of important stations in the service area and of a few mountain stations of Germany are given together with the amount of precipitation and snow data for some German stations, the height of water in neighbouring rivers, a detailed description of the general weather conditions, and finally weather forecasts for the following two days. On the back of the weather map is a short explanation of the signs printed in the map and once in the month a review is given of the course of the weather during the previous month.

2. <u>The accompaniment of any such forecasts by advice of an agricultural character necessitated by weather conditions.</u>

No special emphasis is given to agriculture or horticulture in all this weather station work. An attempt was formerly made to accompany short term weather forecasts by information on, for instance, the beginning of hay harvest, but this was discontinued owing to risk of error. The proper utilisation of the weather information is regarded as a matter for those interested. It is therefore necessary, as has been emphasised above, that farmers and gardeners should accustom themselves to meteorological affairs so that they can use weather

forecasts with a sure understanding. It helps towards that understanding if they themselves carry out a few meteorological observations, for instance, rainfall, air temperature, pressure, wind and cloud, and also have some knowledge of climatic conditions.

Long term forecasts which would be very valuable in this connection have not yet been taken up by scientific meteorology.

Agricultural advisers exist in Germany in large numbers as agricultural teachers, farm advisers, and experimenters, who make use in their advice of the public weather service. A knowledge of normals over a long period is found useful by agricultural advisers and a forecast can be compiled from such normals which sometimes reaches a high degree of probability. The surest and most valuable use of forecasts lies in the knowledge of the climate of new districts and relation of the latter to agriculture. For example, the decision whether a variety of a plant should be grown in a district or not, is one of the most important questions of farm management, and can be solved from a knowledge of the climate. Errors in advice are possible as regards an individual year, but on the average of several years the advice is more certain. Thus a high yielding wheat very susceptible to cold, may suffer heavy damage in some winters, but may be useful over the run of years, while winter oats will always be destroyed by a continental winter. A choice can be made, with a knowledge of the climate, from the two types of spring wheats, viz. that with a long growth period and high yield of inferior quality, and that with a short growth period and with rather lower yield but of better quality. With an average early spring, the first type can be grown, with an average late spring the second. The seeding time of autumn wheat can be determined from a knowledge of the climate. Similar possibilities of forecasting, from a knowledge of the climate, the success or failure of an agricultural operation are very numerous.

3. Use of protective devices against the weather.

The best protective measures against damage by weather are those described above, such as the choice of crops and varieties suitable for the climate, the proper time of seeding, etc. In addition there are certain special protective measures. Detonating against hail is not used in Germany, partly because its utility is not yet proved, but partly also because it would be expected to have little effect in the low lying districts and plains. Frost protection by using smoke clouds when night frosts are forecasted is seldom practised for valuable susceptible plants. Protection of roots and potatoes in the clamp against winter cold is governed by a knowledge of the climate. With a continental winter, a snow covering of 75 centimetres thick is required, in a maritime climate a less thick covering is sufficient. To prevent damage by frost in a continental winter drains must be 1.25 metres deep. The early shooting of roots is increased by lower temperatures at germination and decreased by higher temperatures (apart from inherited characteristics); the time of seeding is therefore to be decided by the course of temperature in spring. Potato harvest is governed by the possibility of autumn frosts, as seed potatoes suffer damage even with a small amount of cold and give a smaller yield in the next year if this is the case. The protection of river districts against damage by floods requires a knowledge of the quantity and intensity of rainfall and also, in winter, of the height and water content of the snow

covering in relation to temperature. Meteorological information in this connection is of great importance to agriculture.

4. The collection at experimental stations side by side of crop data and weather data for the purpose of correlation.

Agricultural meteorological studies by the use of mathematical statistical methods have been begun for general and also for plant physiological purposes more particularly for small or "agricultural meteorological" districts. Investigation of small districts is regarded as necessary in the first place, as the collection of yield figures and related weather data is on a surer basis: in using average figures for larger districts the effect of many factors is eliminated. Later on, when a satisfactory number of small districts have been investigated, the synthesis of the results obtained will lead to surer results for larger districts. The first study from the more general point of view was P. Holdefleiss: on "The effect of weather factors on harvest yields:" a contribution to agricultural meteorology on the basis of observations of meteorological stations of the Department of Crops and Meteorology of the Agricultural Institute of the University of Halle. In this study methods of obtaining correlations were critically examined and a special method of calculation, that of grouping by classes was used. The chief results were the following:-

(1) Yields of peas are favourably affected by warmth and dryness in March and April and by over-average rain and cool weather in May and June.

(2) Yields of potatoes are strongly affected by a warm October of the 'seed' year especially by the average minimum temperature of October.

(3) Growth of pine shoots depends on the rainfall of the previous year, and to a less extent on that of the previous winter, and on the average temperature of April to June.

(4) Yields of winter wheat (grain) are very much influenced by the warmth of March while cool weather in May and June is favourable.

(5) Yields of oats (grain) are favourably affected by comparative dryness in the months 1st January to 31st March.

(6) Comparative dryness in the months 1st January to 31st March is also favourable to grain yield of winter rye. Warmth in March has no influence on winter rye as contrasted with winter wheat.

At the Department for Crops and Meteorology of the University of Halle a few further investigations of the same kind have been carried out, viz.-

(1) by H. Schultz: "The variation of the Barometric 'highs' over central Europe and its effect on crop yields in Germany".

(2) R. Scheinert: "The dependence of yields on weather factors". A short summary of the results is as follows:-

In the centre of the district considered there is a pronounced dry zone, the yearly rainfall of which is below 425 mm. Crops have the following requirements: (a) Wheat. Wheat requires low temperatures in October and November and high ones in January and February. In April and May high rainfall is necessary for a good yield. High January to February temperatures and high April to May, (especially May), rainfall increase the yields and have critical importance.

(b) Rye. Rye is less dependent on weather factors; it loves high humidity at the time of shooting in May and also partly in June, but this must not exceed 1½ times normal. (c) Spring Barley. Spring barley requires high rainfall in April to June. Rainfall is the decisive factor for the yield, so long as its quantity in April to June is not over 180 mm. In certain circumstances the favourable effect of high sunshine duration in March to April and low in May can be increased by the factor of rain. (d) Oats. Oats next to sugar beet have the highest water requirements. Times of seeding and shooting (April to June or May to June) are indisputably critical for yield. Next to rainfall high sunshine duration in March to April decides the yield. Low warmth in June suits the crop. (e) Peas. The conditions with peas were uncertain. This crop seems to be grateful for high rainfall in May, low temperature in June and partly also for low humidity in winter and high warmth in March to April. (f) Sugar beet. For sugar beet yields high June to September rainfall is decisive. High warmth in June is favourable. For the production of sugar content, a rainy August is sufficient but during June and September only little humidity is needed. A long duration of sunshine in September and October increased the quality of the crop.

Only wheat is susceptible to temperature; for all other crops rainfall at certain times is decisive for a good yield. High sunshine duration in March to April and low in May to June is in general good for corn crops.

R. Schultz. "The dependence of yields on weather factors in districts between the Saale Mulde and Elbe".

W. Neustädt. "Agricultural climatological characteristics of Anhalt as the rain protected district of the Harz mountains".

At the Institute for Crops of the University of Göttingen, W. Brouwer has carried out an investigation on the relation between yields and weather in agriculture which is limited to the yields obtained in experiments at Göttingen. The following conclusions were reached:

The correlation co-efficient is a very useful method of finding the relation between yields and weather. In using this method the starting point must be the plant and the stage of vegetation. There are certain rules as to the effect of weather on yields. Yields are strongly influenced by critical factors, during the critical times. Knowledge of critical times and factors and the use of correlation co-efficients and regression equations enabl yields to be forecasted with great certainty long before harvest. Relations between yield and weather should be investigated only for very limited districts with the same soil and weather conditions, as in the experimental field at Gottingen.

L. Gosele at the Institute for Crops and Plant Breeding of the Agricultural High School of Hohenheim carried out investigations on the relation between weather and the yields in agriculture. Here also only the yield figures of the Hohenheim experimental field were used for comparison with the weather data, so that the results have only local importance. The correctness of the results was confirmed by other investigations. As an example of the results obtained the findings about spring barley may be given. As regards the winter humidity from November to March it is stated: Precipitations above 100 mm. in the period November to December had as a rule bad effects on yield. This is explained by the relatively small water requirement of barley. As for wheat, so also for barley, an early warming up of the soil is of great value. With an average temperature in the period January to February of 3° to 6°C good harvests were obtained. All temperatures under 3°C

led to small yields. In March small rainfall was advantageous. In all years of over-average harvests the rain in March was about 120 mm. The optimum quantity of rain in April (seeding and shooting time) is 60 to 80 mm. Quantities of rain outside these limits gave bad harvests. The investigations did not permit of any conclusions on the effect of April temperature and sunshine on the yield. In July (the chief ripening time), the quantity of rainfall should not exceed 80 mm.: the optimum lies between 10-70 mm. The average temperature should be as high as possible; in the worst year this was in July 17.1°C in the best year 20.1°C. The duration of sunshine, providing the foregoing conditions are fulfilled, cannot be sufficiently high.

It should be noted that an average year's rainfall for Hohenheim is 660mm. Göttingen 638mm. and Halle 500mm. Many other agricultural institutes of Germany are working on the plan of dividing the whole of the country into small agricultural meteorological districts and thoroughly investigating these with the object of characterising as exactly as possible the physiological requirements of the different crops. In this work it has already emerged, e.g. that much rainfall is useful in a dry district, but has a bad effect in a wet district; thus the effect of over average rainfall on a sandy soil would be positive, and on a heavy loam or clay negative. Apparent contraditions in the effect of weather factors are thus explained and show the need for these investigations in agricultural science rather than in pure meteorology.

5. The use of meteorological data in crop forecasting.

Crop forecasting in Germany has long been comprehensively and thoroughly organised by the Imperial Statistical Office and naturally rests on the knowledge of the relation between plant growth and yields and the course of the weather of the year. Almost without exception in a wet summer cereal yields have been estimated to be high; and in dry weather they have been estimated to be low, while according to most recent investigations the opposite is the case in many districts. The clearing up of these relationships and their practical use in the organisation of crop forecasting is a task for the future.

6. Account of agricultural meteorological research in the following:-

a) Soils and Manures.

Ehrenberg, P. Die Bodenkolloide, Dresden u. Leipzig 1922. 3. Auflage. s.157 -244.

Gerlach, Nahrstoffverluste durch Niederschlage in feuchten und trockenen Jahren. Mitteilungen der Deutschen Landwirtschafts Gesellschaft. Berlin 43. 1928, Heft 7. S.145-147.

Kaserer, H. Die Beziehungen zwischen Bodentemperatur und Lufttemperatur in ihrem Einfluss auf den Ernteertrag. Fortschritte der Landwirtschaft. Wien u. Berlin. 2 1927, Heft 7. S.205-212.

Remann, E. Bodenkunde. Berlin. 3. Auflage 1908.S.1-64.

b) Plant Physiology.

Feistritzer, W. Der Einfluss verschiedener Klimate auf die Ausbildung des Festigungsgewebes bei Sommerweizen. Dissertation Halle 1922.

Wohlbier, W. Trocken=und Reaktionsschaden im Sommer 1925. Dissertation Halle, 1925. Pflanzenbau. 2, Berlin 1925. Nr.12,S. 193-19.

c) Plant breeding and crop varieties.

Bleschke, G. Einfluss der klimatologischen Faktoren auf Hohe und Gute der Ernteertrage unserer Feldfruchte. Dissertation Breslau 1924.

Engelbrecht, H. Die Landbauzonen der aussertropischen lander. Berlin 1898/99.

Gassner, G. Der Einfluss des Klimas auf die Erntebeschaffenheit des Getreides. Mitteilungen der Deutschen Landwirtschafts Gesellschaft, Berlin, 40. 1925. S. 950-956.

Welker, Erich. Untersuchungen uber die Beziehungen zwischen Klima und Ernteertragen in Wurtemberg. Dissertation Hohenheim 1928.

Knitter, E. Beziehungen zwischen den klimatischen Faktoren und dem Pflanzenbau in Schlesien. Dissertation Breslau, 1925.

Less, E. Ueber die Abhangigkeit der Ernteertrage in Deutschland von Niederschlagen und Temperatur. Landw. Jahrbucher, Berlin 1926. 64. S. 241-296.

Melzer, W. Der Einfluss des Klimas auf die Gestaltung des Landwirtschaftsbetriebes in der Provinz Sachsen. Dissertation Leipzig 1922.

Munzinger, A. Das Klima in landwirtschaftlicher Beziehung. In: Fereboe, Hansen, Roemer. Handbuch der gesamten Landwirtschaft, Berlin 1929. 2. Band S. 95-137.

d) Fruit Growing.

Zielke, W. Untersuchungen uber den Einfluss der Witterung auf die Ernte einiger Obstgattungen und = sorten in Deutschland. Dissertation Halle 1929.

e and f) Insects and Fungus Diseases.

Bodenheimer, F. Die Bedeutung des Klimas fur die landwirtschaftliche Entomologie. Zeitschr. fur angewandte Entomologie, Berlin 12, 1926. Heft 1. S. 91-120.

Mitteilungen der Biologischen Reichsanstalt fur Land= und Forstwirtschaft. Berlin, Verlag P. Parey, Nr. 1-36. 1906. bis 1928.

G) Animal Distribution, Nutrition etc.

Dammann Gesundheitspflege der Haussaugetiere. 3. Auflage. Berlin 1902.

Sohnle Biologische Beitrage zur wurtembergischen Pferdezucht. Hohenheimer Festschrift 1906.

7. Organisation for the collection of phenological data, and use in practical agriculture or agricultural research.

Phenological observations in Germany are founded on the work of Professor Dr. H. Hoffman in Giesson, whose earliest results go back to 1845. In the year 1881 a very good phenological map of central Europe was published in Petermanns Mitteilungen, in which the advent of spring was dealt with. Later Hoffmann's pupil Dr. A. Ihne in Darmstadt continued the organisation of phenological observations and published many correlations. Lastly in a review entitled "What has been the practical utilisation of plant phenology up to the present time?" he issued a new phenological map of the advent of spring in middle Europe in Petermanns Mitteilungen in 1905. Further, in this periodical in March 1916, he published phenological maps of the advent of spring in the British Isles. Since 1922, the Imperial Biological Institute for Agriculture and Forestry in Berlin has organised a Phenological Observational Service with special reference to agriculture. The first publication of this Office on the subject in 1924 was entitled "Results for [illegible] 1922 of the Imperial Phenological Service prepared in the Laboratory for Meteorology and Phenology of the Imperial Biological Institute" by Professor Dr. E. Werth, head of the Laboratory. A further summary is contained in the Mitteilungen of the Institute for December 1927 with the title "Climate and Vegetation Relationships in Germany", again by Professor Dr. E. Werth. Little systematic utilisation of this phenological organisation has been made up to the present in agricultural research; while in practical agriculture numerous phenological observations of local value and according to older methods have been used. The laboratory for Phenology and Meteorology of the Imperial Biological Institute is seeking the further explanation of phenological relationships and their practical utilisation in agriculture.